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United States Department of Agriculture
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Forest Pest Management
Denver, Colorado

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ABSTRACT

The emergence of adult Douglas-fir beetles (DFB), *Dendroctonus pseudotsugae* Hopkins, from their brood trees in 1992 occurred throughout the summer months with a peak in early July, suggesting that there is one annual flight of new adults in this area. A similar density of DFB emerged from trees as overwintered within them, suggesting excellent winter survival. Females comprised 57% of the adults collected. Emergence patterns were similar for both sexes.

Overwintering brood densities of the '92-'93 Douglas-fir beetle generation averaged 29.6 per 36 sq. in. bark sample in November 1992. Brood densities were far higher than 1991 levels. Atypical for DFB, most brood in fall 1992 samples were present in the larval stage, similar to 1990 samples when high brood densities also were found. Gallery starts and total gallery length per bark sample indicated high attack densities and full occupancy of the food resource. About 7 DFB survived to fall 1992 per attacking female, portending a population increase. Natural enemies were not consistently recovered, although they continued at higher levels than found in 1990, the first year following the Clover Mist fire that DFB enemies were sampled.

Aerial survey showed that about 5,600 Douglas-fir were killed by the '90-'91 DFB generation, including numerous groups of 50-400 dead trees. The '91-'92 DFB generation killed some 3,000 trees in the same area. This reduction in tree mortality was ascribed to lower brood production, due, in part, to high winter mortality of the parent generation.

Based on individual tree data and assuming mild to normal winter temperatures, the DFB population might be expected to increase 4 to 10 times from 1992 to 1993. Management alternatives to reduce the impact of the DFB epidemic are discussed and prompt treatment of infested trees is recommended where feasible.

## INTRODUCTION

The Clover Mist Fire of 1988 burned onto the Clarks Fork Ranger District, Shoshone National Forest, generally south of U.S. Highway 212 and Wyoming Route 296 (Forest Route 100). During visits to burned areas in 1989, entomologists determined that large numbers of the Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae), were present in large-diameter, blackened Douglas-fir trees (Pasek, 1990). DFB brood production measured in late fall was low to moderate and most brood were in the callow adult stage.

By 1990, it appeared that an epidemic of DFB was developing in the area adjoining the fire boundary. Most, if not all, areas of large-diameter Douglas-fir adjacent to burned areas likely were infested by DFB in 1990 (Pasek 1991). Groups of DFB-killed trees also were evident in small pockets located at relatively short distances from the fire boundary, as well as on the upper east side of the Clarks Fork canyon, several miles distant. DFB were successfully attacking green, apparently healthy trees, as well as those scorched by fire. This movement from burned to green trees was documented elsewhere in the greater Yellowstone area (Amman and Ryan 1991).

In 1990, total brood production increased dramatically to a density which indicated that the food resource was being fully occupied by beetles (Pasek 1991). The brood, consisting of about half immature and half callow adult stages, appeared healthy and few natural enemies were detected. A cursory examination of the brood in spring 1991 indicated that many DFB (perhaps 75%) did not survive the winter, likely due to prolonged, extremely cold temperatures. The number of trees attacked in 1991 appeared to be similar to the level of damage that occurred in 1990.

In 1991, total brood production dropped to a lower density similar to that observed in 1989. Also similar to 1989 was the stage of overwintering brood, predominantly callow adults. Although the food resource was less fully occupied by beetles, natural enemies of DFB were 10-40 times more abundant, having built up on the beetle population. DFB infested green Douglas-fir because fire-scorched trees were no longer suitable or available. A DFB population increase of 1.5 to 3 times was predicted, barring unusually high mortality.

The purposes of this evaluation were to monitor DFB brood emergence from caged, infested trees to learn more about the timing of DFB attack, to evaluate fall 1992 DFB population levels at several sites on the Clarks Fork Ranger District, and to assess DFB-caused tree mortality via aerial survey.

## METHODS

Eight wire-mesh screen cages (2 sq. ft.) were attached to eight standing, heavily-infested Douglas-fir at Camp Creek, the Cathedral Cliffs Sale area, and near the K-Z Ranch on 5-6 May 1992. Adult DFB were collected approximately each week until 18 August 1992. Collected DFB were transported to the Rapid City Service Center office, where they were counted and their sex determined.

Bark samples (approximately 6 by 6 inches) were removed at a height of 5-7 feet from the north and south sides of each of 10 Douglas-fir trees currently infested by DFB per plot on 3-5 November 1992. Plots were located at Camp Creek, the K-Z Ranch area, the Reef Creek Picnic Ground and on the eastern side of the Reef Creek drainage at an elevation about 600 feet above the Picnic Ground. DBH was recorded for each sample tree. Live DFB and DFB natural enemies dislodged from the bark sample during removal were identified, counted, and discarded. Bark samples were stored in plastic bags and transported to the Rapid City Service Center office, where they were examined. Number of gallery starts was counted and total inches of egg gallery were measured for each bark sample. Phloem was shaved with a knife to locate all remaining

live insects in each sample. Numbers of live DFB brood were tallied by life stage and DFB natural enemies counted. Means and standard deviations by sample site were calculated for all variables measured.

Aerial observation flights were conducted on 20 August 1992 and 29 June 1993. Douglas-fir mortality was sketch mapped by two observers. Visible DFB-caused mortality is a result of DFB attacks the previous summer and is evident from the air as entire tree crowns faded in color to pale yellow or brownish-red. The area for which results are reported is along the canyon of the Clarks Fork of the Yellowstone River from the confluence with Crandall Creek south to the confluence with Sunlight Creek, including the Windy Mountain area and the Russell Creek drainage. Mapping results were tallied using an electronic planimeter and standard methodology.

## RESULTS AND DISCUSSION

In 1992, adult DFB beetles emerged all summer from their brood trees (Fig. 1). However, samples up to and including 6-9 July account for 86% of all DFB collected, showing that most emergence occurred by early July. Similarly, most emergence occurred in June during 1990 (Pasek 1991), indicating that DFB emergence is later in the Clarks Fork area of Wyoming than that reported for southern Idaho (Furniss 1962). The 1992 pattern of emergence over time at each of the three sites followed the same bell-shaped distribution with one mid-summer peak. The pattern was shifted in time between sites; the one cage at the Cathedral Cliffs Sale area reached peak numbers of DFB on 11 June, the three cages at Camp Creek and the four cages near the K-Z Ranch all reached peak numbers on 27 June. Emergence was atypically concentrated in late July from two trees at the K-Z Ranch site, accounting for all DFB trapped on 26 July. In 1992, the caging period was continued for more than one month beyond the caging period in 1990 (Pasek 1991), yet emergence results were similar except for the detection of additional emergence in August of 1992. Because adult DFB can re-emerge and attack additional trees, the attack period is not fully described by these results. It is likely that DFB may actively search for host trees throughout the summer; however, they may not be sufficiently numerous to successfully attack standing, green trees at times other than near peak emergence in mid-summer. The impact of a large proportion of overwintering brood present in immature life stages upon adult emergence pattern is not yet known, since the '89-'90 and '91-'92 DFB generations overwintered mainly as callow adults.

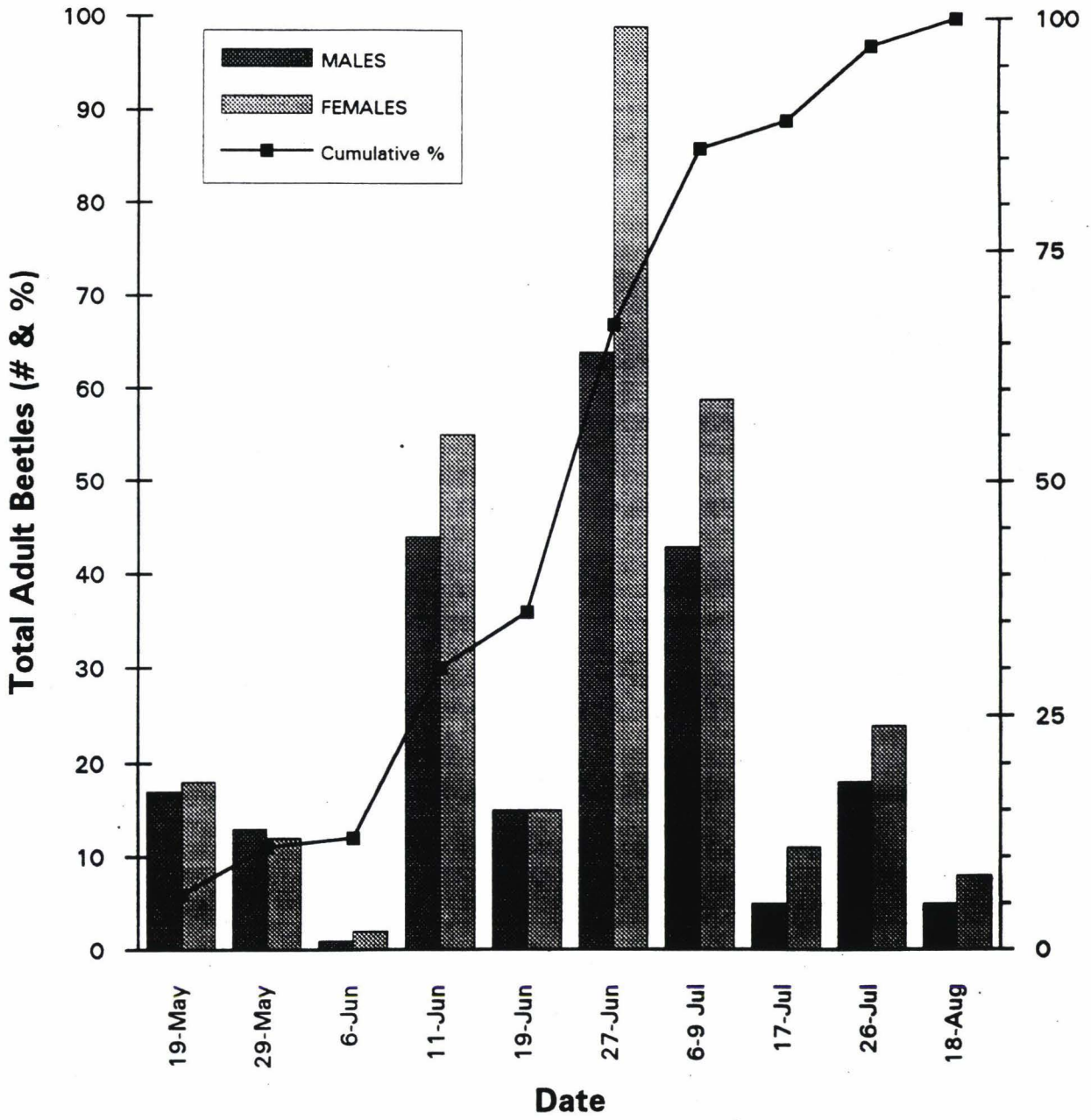
A total of 542 adult DFB were collected from emergence cages. This equates to 33.9 adult DFB per square foot of bark surface or 8.5 DFB per 36 sq. inches. Thus DFB adult emergence was about equal to the total overwintering brood estimated in 1991 (Fig. 2; Pasek and Schaupp 1992), suggesting high winter survival. Brood for this '91-'92 DFB generation overwintered predominantly as callow adults, resembling the pattern of the '89-'90 DFB generation that also had excellent overwintering survival (Fig. 2; Pasek 1991). Females comprised 57% of all DFB collected. There was no sex-specific pattern of emergence evident other than the larger-than-usual preponderance of females (61%) on the peak date of 27 June (Fig. 1).

Mean brood production in fall 1992 differed somewhat between sites, yet was consistently high (Table 1). Such brood production levels are similar to those found in November 1990 (Pasek 1991), the second DFB generation following the fire, and are far higher than those found in 1989 or 1991 (Fig. 2). The high DFB density within trees means that the food resource was fully occupied. Such trees have the potential to produce large numbers of adult DFB. Although unsuccessfully attacked trees were found, in which there was little or no brood production, the number or proportion of unsuccessfully attacked trees was not determined.

Average DBH of sample trees in 1992 was 21.4 in. (Table 1), consistent with the finding that DFB successfully attacks larger diameter trees (Pasek 1990). The average DBH varied little between the four sites sampled.

New or callow adults, the typical overwintering stage of DFB, comprised only 21% of the life stages in all samples (Table 1). Larvae were consistently present, accounting for 78% of the life stages in all samples, while only 1% of the DFB brood were in the pupal stage. No eggs were found. The relative abundance of DFB life

**Fig. 1. Douglas-fir beetle emergence into eight cages, Cathedral Cliffs area, Wyoming, 1992**



## Fig. 2. Douglas-fir beetle, overwintering brood by year, Cathedral Cliffs area, Wyoming

(bars show 1/2 standard error of overall mean)

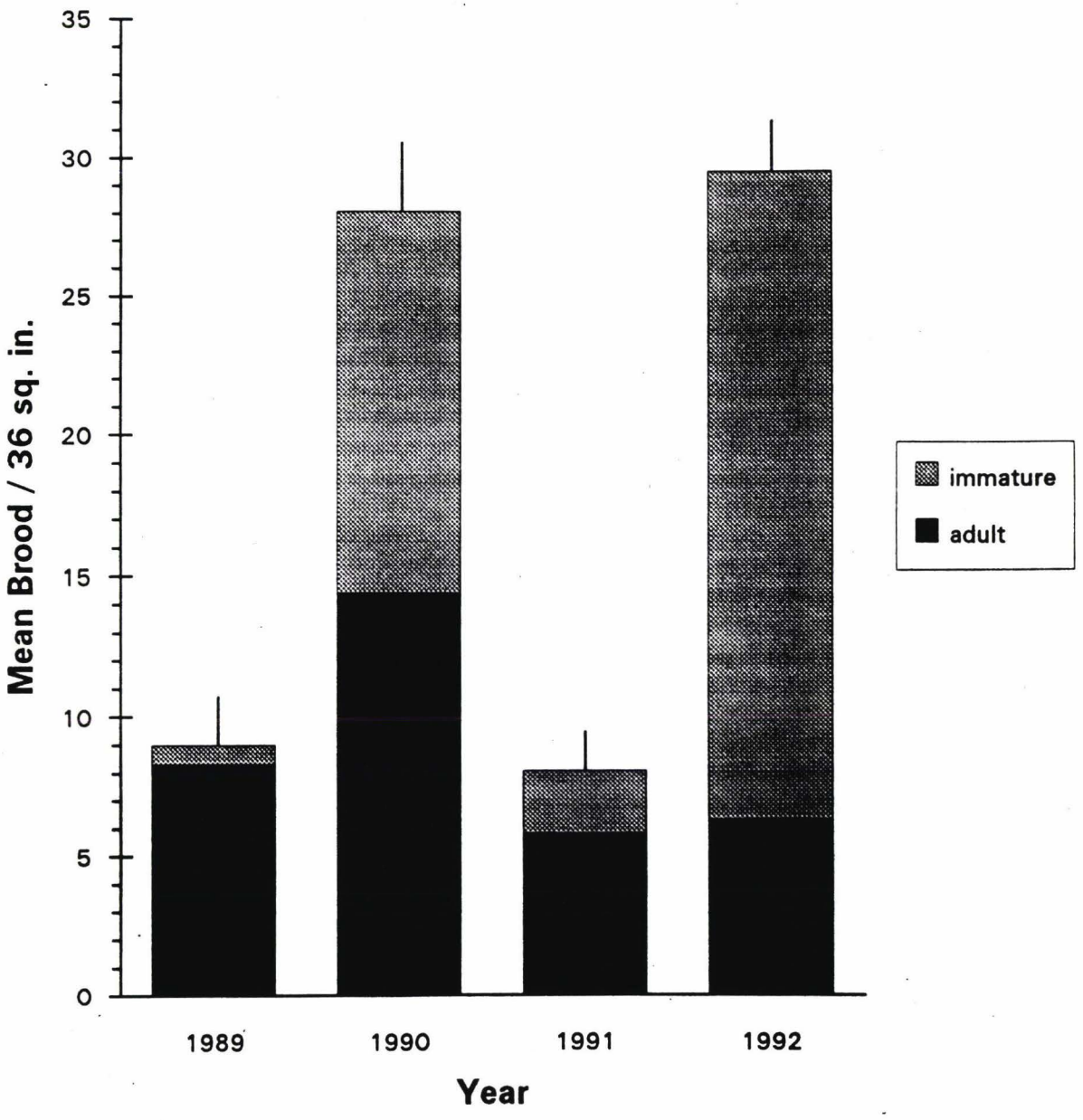


Table 1. Douglas-fir beetle overwintering brood production per 36 square inches of bark surface of samples taken at 5-7 feet height on 10 successfully attacked trees per plot, November 1992, in the Cathedral Cliffs area of the Clarks Fork Ranger District, Shoshone National Forest, Wyoming (means ± standard deviation).

| PLOT NAME | DBH | ASPECT | NO. OF SAMPLES | EGGS | LARVAE | PUPAE | NEW ADULTS | TOTAL BROOD |
|---|---|---|---|---|---|---|---|---|
| Camp Creek | | N | 10 | 0 | 27.10 ± 14.90 | 0.10 ± 0.32 | 4.70 ± 7.67 | 31.90 ± 13.50 |
| Camp Creek | | S | 10 | 0 | 20.10 ± 13.77 | 0.00 ± 0.00 | 5.60 ± 6.08 | 25.70 ± 12.91 |
| CC Average | 23.81 ± 3.79 | | 20 | 0 | 23.60 ± 14.42 | 0.05 ± 0.22 | 5.15 ± 6.75 | 28.80 ± 13.25 |
| K-Z Ranch | | N | 10 | 0 | 19.00 ± 15.53 | 0.10 ± 0.32 | 10.30 ± 7.79 | 29.40 ± 16.54 |
| K-Z Ranch | | S | 10 | 0 | 8.30 ± 5.77 | 0.20 ± 0.42 | 10.40 ± 11.51 | 18.90 ± 16.68 |
| K-Z Average | 19.14 ± 4.48 | | 20 | 0 | 13.65 ± 12.65 | 0.15 ± 0.37 | 10.35 ± 9.57 | 24.15 ± 17.04 |
| Reef Creek PG | | N | 10 | 0 | 20.90 ± 11.49 | 0.40 ± 0.70 | 5.60 ± 5.32 | 26.90 ± 11.62 |
| Reef Creek PG | | S | 10 | 0 | 18.30 ± 7.94 | 0.80 ± 1.23 | 11.30 ± 12.00 | 30.40 ± 12.30 |
| RC-PG Average | 21.00 ± 4.05 | | 20 | 0 | 19.60 ± 9.71 | 0.60 ± 0.99 | 8.45 ± 9.50 | 28.65 ± 11.78 |
| Reef Creek | | N | 10 | 0 | 31.80 ± 14.78 | 0.00 ± 0.00 | 0.80 ± 1.23 | 32.60 ± 14.73 |
| Reef Creek | | S | 10 | 0 | 38.80 ± 15.86 | 0.10 ± 0.32 | 1.80 ± 2.25 | 40.70 ± 16.04 |
| RC Average | 21.50 ± 5.32 | | 20 | 0 | 35.30 ± 15.35 | 0.05 ± 0.22 | 1.30 ± 1.84 | 36.65 ± 15.55 |
| Overall Average | 21.36 ± 4.67 | | 80 | 0 | 23.04 ± 15.21 | 0.21 ± 0.59 | 6.31 ± 8.21 | 29.56 ± 14.97 |

stages in 1992 samples resembled that of 1990 samples, when 56% callow adults were found (Pasek 1991), but was even more skewed toward larvae. Unlike the 1990 situation (Pasek 1991), brood development did not seem related to the distance from intensively burned trees. The relatively cool summer temperatures may have had a role in what may be an unusually high percentage of DFB overwintering as larvae. It is not known how stage-of-brood development affects DFB overwintering survival. Several workers in other regions have observed DFB population collapse concurrent with an increase in the proportion of immature stages in overwintering DFB brood (Chansler 1968; Furniss et al. 1979). Samples in 1989 (Pasek 1990) and 1991 (Pasek and Schaupp 1992) were comprised mainly of callow adult DFB and subsequent survival appeared to be excellent.

Differences in brood densities between north and south samples were generally small, showing no consistent pattern. There was a clear trend toward more adults on the south side and more immatures on the north side of trees, perhaps because the south side was warmer and, therefore, development was faster. This trend, though less clear, also was evident for 1991 brood samples (Pasek and Schaupp 1992).

Samples averaged 2.3 gallery starts per 36 sq. in. (9.2 per sq. ft.) with little variation (Table 2), indicating uniform attack densities among successfully colonized trees. This is somewhat higher than the range of 4-8 gallery starts per sq. ft. that is considered to indicate maximum brood production (McMullen and Atkins 1961). Density of gallery starts in 1992 equals that of 1991 (Pasek and Schaupp 1992) and is higher than that of 1990 (Pasek 1991), when it was at the high end of the reported range for maximum brood production. The high attack density indicates that the DFB population was still large enough to effectively mass attack hosts.

Mean total egg gallery length per bark sample varied by site ranging from about 22 to 35 in. per 36 sq. in. (88 - 140 in. per sq. ft.). Such galleries were among the longest averages recorded by site or overall (Pasek 1991; Pasek and Schaupp 1992) and exceed the range of 30 - 60 in. per sq. ft. that reportedly represents maximum brood production levels (McMullen and Atkins 1961). Some intra-specific competition is likely at these higher attack and gallery densities, and may contribute to reduced brood survival.

DFB natural enemies were not consistently recovered at all sites (Table 2). The K-Z Ranch site had the fewest samples with no wasp or fly DFB enemies (3 for both categories). Reef Creek Picnic Ground had 8 and 7 samples with no wasp or fly DFB enemies, respectively, while more samples tended to have zero counts at Camp Creek (11 and 4) and Reef Creek (17 and 14). The Reef Creek site had about the same number of DFB enemies per sample as the overall low values from 1990 (Pasek 1991). The highest DFB enemy numbers were obtained at the K-Z Ranch site and were about the same as overall averages from 1991 (Pasek and Schaupp 1992). Over all sites, 1992 DFB enemy numbers were about the same for flies and down by half for wasps compared with 1991 (Pasek and Schaupp 1992). In 1992, parasitic wasps, particularly cocoons of the braconid *Coeloides* sp., were about equally abundant as larvae of *Medetera* sp., a predatory fly, in bark samples (Table 2). As in previous years, few predatory beetle larvae (Cleridae) were found. Samples likely were collected after most clerid larvae had already migrated to the root collar where they overwinter in the outer bark or duff (Marsden et al. 1981); clerid larvae were quite common under the bark in May 1992 (WCS, personal observation). Natural enemy density showed little variation by aspect, except that four trees at the K-Z Ranch site had 9-12 *Coeloides* sp. cocoons on the north, but only 2-4 on the south sides.

The high numbers of surviving brood in the 1992 samples likely offset the impact of DFB natural enemies, which were still fairly common. After building from relatively low levels in 1990 when the DFB epidemic began (Pasek 1991), insect natural enemies of DFB brood have remained at increased levels due to the continuing presence of large numbers of DFB hosts. Natural enemies were predicted to attack the 1992 brood in relatively high numbers (Pasek and Schaupp 1992); however, an increase in DFB insect natural enemies from 1991 to 1992 was not evident. Although not sampled, there are many other DFB enemies, including predatory and parasitic insects, nematodes, mites, and insectivorous birds that may affect DFB population levels.

Surviving DFB brood in fall samples, as summarized by Figure 2, display two large increases, one from 1989 to 1990, and the other from 1991 to 1992. Before the fall DFB brood matures and attacks other trees the

Table 2. Douglas-fir beetle overwintering brood gallery characteristics and natural enemy numbers per 36 square inches of bark surface of samples taken at 5-7 feet height on 10 successfully attacked trees per plot, November 1992, in the Cathedral Cliffs area of the Clarks Fork Ranger District, Shoshone National Forest, Wyoming (means ± standard deviation).

| PLOT NAME | ASPECT | NO. OF SAMPLES | GALLERY STARTS | GALLERY LENGTH | BEETLE DFB ENEMIES | FLY DFB ENEMIES | WASP DFB ENEMIES |
|---|---|---|---|---|---|---|---|
| Camp Creek | N | 10 | 2.50 ± 1.35 | 29.30 ± 9.79 | 0.20 ± 0.42 | 1.10 ± 0.88 | 1.90 ± 2.88 |
| Camp Creek | S | 10 | 1.80 ± 0.92 | 26.90 ± 12.54 | 0.20 ± 0.42 | 1.70 ± 1.49 | 1.00 ± 1.70 |
| CC Average | | 20 | 2.15 ± 1.18 | 28.10 ± 11.02 | 0.20 ± 0.41 | 1.40 ± 1.23 | 1.45 ± 2.35 |
| K-Z Ranch | N | 10 | 2.30 ± 1.06 | 32.10 ± 8.79 | 0.10 ± 0.32 | 3.00 ± 2.21 | 5.60 ± 5.36 |
| K-Z Ranch | S | 10 | 3.20 ± 0.63 | 37.80 ± 10.59 | 0.10 ± 0.32 | 3.10 ± 2.42 | 2.70 ± 1.95 |
| K-Z Average | | 20 | 2.75 ± 0.97 | 34.95 ± 9.91 | 0.10 ± 0.31 | 3.05 ± 2.26 | 4.15 ± 4.20 |
| Reef Creek PG | N | 10 | 2.00 ± 0.94 | 28.60 ± 8.09 | 0.00 | 1.70 ± 2.06 | 1.40 ± 1.90 |
| Reef Creek PG | S | 10 | 2.40 ± 0.70 | 30.70 ± 7.38 | 0.10 ± 0.32 | 2.40 ± 2.07 | 1.30 ± 1.34 |
| RC-PG Average | | 20 | 2.20 ± 0.83 | 29.65 ± 7.61 | 0.05 ± 0.22 | 2.05 ± 2.04 | 1.35 ± 1.60 |
| Reef Creek | N | 10 | 1.50 ± 0.97 | 21.40 ± 5.95 | 0.00 | 0.30 ± 0.67 | 0.10 ± 0.32 |
| Reef Creek | S | 10 | 2.30 ± 0.82 | 21.60 ± 5.40 | 0.00 | 0.70 ± 1.06 | 0.50 ± 1.27 |
| RC Average | | 20 | 1.90 ± 0.97 | 21.50 ± 5.53 | 0.00 | 0.50 ± 0.89 | 0.30 ± 0.92 |
| Overall Average | | 80 | 2.25 ± 1.03 | 28.55 ± 9.87 | 0.09 ± 0.28 | 1.75 ± 1.91 | 1.81 ± 2.90 |

following summer, biotic and mainly abiotic mortality factors will lower the population size. This mortality is unpredictable. For example, using the number of DFB brood per attacking female, in the absence of severe winter temperature conditions, a population increase of about 1.5 to 3 times was predicted for 1992. As Figure 2 shows, this prediction was conservative, though fairly close, as an increase of 3.7 times was documented. Using the same procedure, population increases of 4.4 (K-Z Ranch site) to 9.7 (Reef Creek site) would be predicted for 1993, with a mean of 6.6 for all sites combined. Because of the many influences acting on DFB and its host tree, however, such population predictions are very difficult to translate into predictions of Douglas-fir mortality.

Douglas-fir mortality due to DFB is visible from the air by the presence of faded foliage approximately 1 year following attack by DFB parents. These parents would have developed from brood that overwintered the previous fall. Therefore, it is nearly 2 years after fall overwintering brood sampling until evidence of tree mortality resulting from this brood can be assessed. This means that adults developing from the 1990 overwintering DFB brood in Figure 2 were responsible for attacking the trees that faded in the summer of 1992. These 1992 faders were sketch-mapped from the air, totalling some 5,585 trees (Table 3). This is a large number of dead Douglas-fir concentrated in a small area; numerous group kills of 50-400 trees were mapped. A dramatic increase in 1992 in the number of faded Douglas-fir was reported by casual ground observers, as compared with 1991. The 1991 DFB overwintering brood (Figure 2) was 71% less numerous per average sample than the 1990 brood. This reduced brood production in 1991 is likely due to cold temperatures in the '90-'91 winter that decimated the parent population (Pasek and Schaupp 1992). The reduction in brood production from 1990 to 1991 was reflected in a 48% reduction in the number of Douglas-fir attacked in 1992 and sketch-mapped as faded trees in 1993 (Table 3). Although the magnitude of population change based on brood samples does not exactly mirror changes in tree mortality, it can give a reasonable estimate of trend. Using aerial survey techniques, it will not be possible to determine the amount of Douglas-fir mortality caused by adults which develop from the fall 1992 DFB overwintering brood until summer 1994. However, judging from evidence on hand and barring unusually high DFB mortality, a significant increase is expected in the number of faded Douglas-fir in the area next year. It is likely that the DFB epidemic will continue until suitable host resources are depleted and/or DFB mortality rises above current levels.

Table 3. Douglas-fir mortality from Douglas-fir beetle infestation using aerial survey data taken 20 August 1992 and 29 June 1993, by Forest Health Management staff over the same Cathedral Cliffs area on the Clarks Fork Ranger District, Shoshone National Forest, Wyoming.

| Year Tree Attacked | Year Tree Fades | Number of Trees Killed | Acres Affected | Volume Killed * |
|---|---|---|---|---|
| 1991 | 1992 | 5,585 | 2,324 | 309 |
| 1992 | 1993 | 2,924 | 935 | 162 |
| | % change ** | (-48%) | (-60%) | (-48%) |

* Volume in thousands of cubic feet of timber using 55.35 cu. ft. per tree
** Calculated as (('93-'92)/'92 X 100

## ALTERNATIVES

Several methods are available to reduce populations of DFB and the resultant tree mortality. These pest management strategies may focus on the reduction of infested material, reduction of susceptible host material, or prevention of new attacks. The decision to use a particular method should be predicated on considerations of stand conditions, location, management objectives, economic factors, and other pertinent variables.

Alternative 1:

**Sanitation Harvesting** - Fell infested trees and remove them from the site for mill processing prior to adult DFB emergence. Stands with the highest percentages of large-diameter Douglas-fir should be given priority.

*Where to use* - Sites with the following conditions are appropriate: accessible to logging operations such as near existing roads or where roads can be readily constructed; less than 40% slope; where disturbance by man will not adversely affect special resource values; and in proximity to high value areas that need to be protected.

*Advantages* - Beetle broods can effectively be eliminated in small loci by removing all infested trees prior to beetle emergence. Beetle populations in larger groups can be significantly reduced. Sanitation harvesting provides a degree of protection to surrounding, uninfested trees by removing a nearby source of attacking beetles, recovers timber volume that otherwise would be lost, reduces fuel load, reduces subsequent hazard from falling trees and inaccessibility to large animals, reduces visual impact of dead and dying trees, and will encourage regeneration and greater diversity of size and age classes across the forest.

*Disadvantages* - Short implementation time is required; trees must be removed prior to adult emergence in the spring following attack. Adverse disturbance of the site and soil is possible. Sanitation harvesting removes tree cover in spots or at a density considered adverse aesthetically.

Alternative 2:

**Tree Baits** - Commercially available DFB tree baits containing attractant semiochemicals (aggregation pheromone) can be used to concentrate beetles in trees that can be subsequently harvested. Baits are deployed just prior to beetle flight (May) and baited trees must be felled and removed or destroyed prior to the next adult emergence period (i.e., within 1 year).

*Where to use* - Ideal sites for placement of baits would be Douglas-fir trees in and around salvage operations. Baited areas must be suitable for harvest (alternative 1) or mechanical control (alternative 3). Baiting is likely to be most effective in areas where beetle populations are small; e.g., it is useful as a mop-up operation following removal of infested trees. Baiting is not suitable for large population centers; the native beetle population quickly overwhelms the baits in this situation.

*Advantages* - Baiting may provide some degree of redirection of beetle attacks to trees where salvage can be implemented. Beetles emerging from infested trees that were missed during salvage harvesting in one year may be concentrated in logs or trees for removal the following year.

*Disadvantages* - Application is generally limited to sites accessible to harvest and where beetle populations are low and relatively isolated from larger population centers.

Alternative 3:

**Mechanical Control** - Fell and buck infested Douglas-fir trees and treat them by burning, peeling the bark, or chipping the logs.

*Where to use* - Use in unroaded areas or on steep slopes that are accessible on foot (or horseback) to logging but where roadbuilding or skidding is undesirable. Sites where no logging company is interested in bidding on the timber or volume is too small to put up a sale also are appropriate.

*Advantages* - Much of the beetle brood can be eliminated even in the absence of a timber market. Mechanical control provides a degree of protection to surrounding, uninfested trees by removing a nearby source of attacking beetles. It also reduces subsequent hazard from falling trees and inaccessibility to large animals, reduces visual impact of dead and dying trees, and will encourage regeneration and greater diversity of size and age classes across the forest. Potential for site and soil disturbance is less than for alternative 1.

*Disadvantages* - Mechanical control is labor intensive, does not recover value and volume from trees, leaves a high fuel load on the site, removes tree cover, and requires a short implementation time; trees must be treated prior to adult emergence in the spring following attack.

Alternative 4:

**Trap Trees** - Green trees can be felled and left on the site to attract beetles. Felled logs are sprayed with carbaryl in April or May, just prior to the beetle-attack period, so that beetles will be killed as they enter the logs. Tree baits can be used on felled logs to increase their attractiveness to beetle attack.

*Where to use* - Use in small infestation pockets where salvaging, mechanical control, or re-entry is impractical. Also use in unroaded areas or on steep slopes that are accessible on foot (or horseback) to logging but where roadbuilding or skidding is undesirable. Sites where no logging company is interested in bidding on the timber or volume is too small to put up a sale also are appropriate. Trap trees may be used as a tool to mop-up a population following salvaging.

*Advantages* - Use of trap trees concentrates beetle attack away from trees where protection is desired, kills beetles, does not require sale preparation and administration, can be used on sites with steep slopes or where roads do not exist and are not desirable, and is not as labor intensive as mechanical control.

*Disadvantages* - Use of trap trees does not recover value and volume from trees, leaves a high fuel load on the site, and removes tree cover.

Alternative 5:

**Silvicultural Treatment** - To reduce susceptibility in green stands, basal area should be reduced below 80% of normal stocking (Furniss et al. 1981). Mature and overmature stands of Douglas-fir can be harvested. Younger stands should be thinned periodically to improve vigor and reduce moisture stress.

*Where to use* - This is a preventative treatment that should be considered as an ongoing part of the regular timber program. Due to limited staffing and funding,

this alternative is not suitable during an epidemic where resources are better spent on other options.

*Advantages* - Silvicultural treatment reduces susceptibility of stands to beetle attack, which may limit tree mortality and infestation size in the event of a future increase in beetle population.

*Disadvantages* - This alternative is not suitable for sites where harvesting activity is not desirable, such as in wilderness, on steep slopes, or where visual quality would be adversely impacted.

Alternative 6:

**Protection of High Value Trees** - Prior to beetle flight in early spring (April or May), the boles of valuable trees can be sprayed with carbaryl to prevent DFB attack.

*Where to use* - This method would be appropriate for use in and around campgrounds and private homes. Trees must be of high value. Insecticide application is not effective for trees that have already been infested.

*Advantages* - Insecticide application provides a degree of protection not currently available through other mitigation strategies. Carbaryl has a low mammalian toxicity and low residual activity, which means it remains in the environment for a short period of time.

*Disadvantages* - Efficacy for protection of Douglas-fir needs to be demonstrated by a test prior to operational usage. Material is toxic to other insects as well as to DFB. Many citizens have concerns about environmental contamination and safety. Insecticide application does not effectively reduce the existing beetle population, is expensive if very many trees are treated, and size of treatment areas needs to be small due to cost and labor considerations.

Alternative 7:

**Repellents** - A granular controlled-release formulation of the DFB anti-aggregative pheromone, 3-methyl-2-cyclohexen-1-one (MCH), can be broadcast or aerially applied to stands where protection is desired. This alternative currently requires an experimental use permit, because registration of the material with EPA is not yet completed.

*Where to use* - The method is most suited for high value and inaccessible stands that are not currently infested but are threatened by nearby beetle populations.

*Advantages* - MCH is nontoxic; it is a natural chemical that is produced by DFB. Use of MCH is a promising method of preventing new attacks.

*Disadvantages* - MCH does not directly reduce the existing beetle population. Granular application distributes plastic pellets into the environment. Availability of the material may be a problem. MCH is not yet registered and has not been tested to determine the efficacy for protection of standing, green trees.

Alternative 8:

**Do Nothing** - Accept tree mortality caused by DFB as a natural phenomenon.

*Where to use* - Use where other control alternatives cannot be effected or are not desired. This may be the only viable alternative for infested stands that are inaccessible, areas designated as wilderness, and sites where the visual and erosive impacts of harvesting are a major concern.

*Advantages* - No unnatural site disturbance or introduction of foreign materials into the environment will occur. Change in vegetation follows a natural event.

*Disadvantages* - The no-action alternative allows the beetle population to continue to increase and threaten additional sites. Tree volume and value is lost, visual quality is adversely affected by dying and dead trees, fuel load increases, tree hazard increases, inaccessibility to large animals increases with time as trees fall over, and tree regeneration is inhibited due to shading by remaining dead trees and lack of seedbed preparation.

## RECOMMENDATION

Alternative 1 should be considered wherever feasible and economical within the suitable timber base to remove as many infested trees as possible. Where management objectives would otherwise be adversely affected, newly-attacked trees should be located each summer during the course of the epidemic, and sanitation sales should be prepared and implemented prior to DFB adult emergence each year for several years until DFB populations sufficiently decline.

Luring DFB to standing, green trees (Alternative 2) does not work well in epidemic situations where the natural pheromone of the beetles overwhelms the artificial baits. This alternative is not recommended at present.

Alternative 4 may be appropriate where baits can be used to lure DFB to log decks for subsequent removal. Successive baiting and sanitation harvesting may be needed.

Alternative 5 should be considered for long-range management planning to increase the health of forest stands and reduce susceptibility to DFB attack. The magnitude of the current DFB epidemic puts it beyond the level that is manageable using currently available techniques. An effective forest management program that includes silvicultural treatment would provide greater environmental resistance to DFB epidemics in the future.

Alternative 8 may be selected of necessity in much of the Clarks Fork Ranger District because of the extensive areas of wilderness affected by the Clover Mist Fire, concerns for the protection of certain wildlife species, the presence of inaccessible areas, the concern for visual and erosive impacts of harvesting options, and the constraints on time and manpower available to treat damaged sites.

Land managers need to develop site-specific plans to manage stands to reduce the impact of DFB where feasible. Alternatives should be carefully weighed in relation to site-specific characteristics. Forest Health Management personnel will continue to assist in re-assessing DFB population and damage levels as needed during the course of the infestation.

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